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VISUAL PERCEPTION OF ELEVATION

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20 January 1992

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PROJECT TITLE: VISUAL PERCEPTION OF ELEVATION

SPATIAL ORIENTATION PROGRAM, DIRECTORATE OF LIFE SCIENCES
PROGRAM MANAGER: DR. JOHN TANGNEY
DEPARTMENT OF THE AIR FORCE
BOLLING AIR FORCE BASE, DC 20332

PROGRESS REPORT: Jan. 1, 1991-Dec. 31, 1991

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Date Submitted: Jan. 20, 1992

We have accomplished a great deal during 1991. Quantitatively, this includes a total of 6 experiments at the laboratory at Columbia University which involved the running of 24 subjects (9 different individuals), and a single experiment in the slow rotation room at Brandeis University in which the running of 14 subjects is nearly complete. Some new experimental setups were required at each institution in order to run some of these experiments. In addition, a good deal of progress has been made in the development of significant theory. Four articles are in press (publication in 1992), a fifth has been submitted; several more articles are in progress (several others are in the planning stage). There were 8 published abstracts of presentations at a total of 5 professional meetings in 1991, and 2 more abstracts have been submitted for presentation at a meeting in 1992. The principal investigator presented colloquia at 3 institutions.

A list of publications, abstracts, and colloquia is appended below. Preprints of articles and reprints of abstracts are enclosed herein.

A. Experiments at Columbia University

The new experiments have extended our previous work demonstrating the fundamental importance of the retinal orientation and location of individual straight lines and the irrelevance of other aspects of the stimulation for the aspects of egocentric spatial localization and orientation with which we have been primarily concerned, visually perceived eye level (VPEL). The work completed and in progress can be summarized in terms of five sorts of efforts:

1. We have discovered that the particular depth plane containing the lines that produce an influence on VPEL is immaterial to the influence. That is, if an oblique line from an erect plane and a pitched-from-vertical line from a pitched-only plane stimulate the same retinal locations, both will have the same influence on VPEL. The significant aspects of the retinal stimulus is the retinal orientation and location. (cf., Figs. 16 and 17, in preprint of Article 2). From the point of view of the aspects of egocentric spatial localization and orientation with which we have been concerned the difference between stationary stimuli from pitched and from erect planes is insignificant.

Not only is the depth plane irrelevant, but differences between monocular and binocular viewing, the state of lens accommodation and pupil diameter, the gradient of width, distribution of luminous flux in the stimulus, and image sharpness are also irrelevant (cf., discussion in preprint of Article 1, section on "Insignificance of three retinal gradients"; also in Article 2 in sections "Insignificance of binocular cues", "Insignificance of several monocular gradients").

2. We have extended our experiments to include measurements of the orientation within the frontal plane visually perceived as vertical (VPV). We have measured a systematic influence of two rolled-from-vertical lines in an erect plane on VPV (cf., Article 2, Figs. 18 and 19). Here also, we obtain identical effects from pitched lines presented to identical retinal locations. In this case, two pitched-from-vertical lines from planes of equal and opposing pitch yield identical results.

In brief summary of 1 and 2 above we can say that a pitched-from-vertical line from a pitched plane and a rolled-from-vertical line from an erect plane have identical effects on each of two different aspects of egocentric spatial localization and orientation: VPEL and VPV.

3. We have extended the set of stimulus parameters across which we have examined the conclusion that the influences on VPEL from parallel lines summate along an exponential with 15° space constant but that the influences from nonparallel lines are combined by a mechanism that takes a weighted average of their influences (which for two lines is an opponent process-type weighting). Here, we have measured VPEL for all 49 combinations of pitch of two lines, with each of the two lines at one of 7 orientations. (Abstract 10). Some of this work has not yet been reported; this includes work with different length lines at different eccentricities.

4. Some further extensions of basic parametric work have been carried out. This includes using shorter length lines than previously employed at different heights in the visual field in an experiment in which the rotation axis was kept fixed at each height. This provides greater resolution of the height variable; again it appears that a bias effect only is obtained without any influence on the slope of the VPEL-vs-pitch function.

We have begun some work in which horizontal lines are placed on the side walls of the totally dark erect pitchroom. Our indications are that substantial effects on VPEL result from pitching the room although the field in front is dark. More ocomplete experiments are in progress.

We had previously determined the time course for the influence of the fully illuminated visual field on VPEL. We have now done the same for the 2-line stimulus. For both, the course of light adaptation is essentially complete in under 1 minute; dark adaptation is only inconsistently faster following exposure to the 2-line stimulus than following exposure to the fully illuminated pitchroom. The article reporting the dark adaptation work is being revised to include the 2-line work before sending in a final version. The adaptation work is submitted for presentation at ARVO in 1992. I note without further comment at this point that the 4-5 minute time constants for decay of the influence on VPEL are 8 - 10 times longer than have previously been reported for pattern vision (e.g., spatial frequency adaptation) where a cortical locus of adaptation has been suggested.

Experiments have begun in which linear arrays of visible point stimuli replace the continuous lines of the 2-line stimulus. Measurements are being made on VPEL with varying numbers of points.

5. We have determined that changing head orientation around an axis through the eyes (over a 60° range; $\pm 30^\circ$) has no substantial influence on the VPEL setting or on the influence exerted by a 2-line pitched-from-vertical

stimulus. We have also determined that horizontal change of eye position has almost no influence on VPEL. These results imply that the influence on the VPEL discrimination of the pitched-from-vertical lines is near-spatiotopic for eye position (cf., Abstract 8). We had previously reported that variation of horizontal retinal eccentricity of the symmetric 2-line stimulus produced a substantial change in the slope of the VPEL-vs-pitch function (ARVO, 1990). The combination of that result with the spatiotopic results has led us to some further theoretical treatment in which we are presently involved.

We've also begun some experiments in which a 2-line horizontal stimulus is slanted (rotation around a vertical axis). We are also beginning to work with subjects lying on their sides who view pitched-from-vertical and slanted-from-horizontal 2-line stimuli. Our first indications are that these extensions will be nontrivial and will yield some significant surprises.

B. Experiments at Brandeis University

We have employed the 2-line stimulus in the slow rotation room with subjects at 1.5 G. The experimental paradigm involves VPELs in total darkness with the room stationary or rotating, and VPELs while viewing the 2-line stimulus with the room stationary or moving. For each of the subjects the 2-line stimulus is viewed at each of 7 pitches. We have collected full data on 12 subjects and partial data on 2 more.

Our measures of the elevator illusion at 1.5 G (deviation of VPEL under increased G in total darkness from values at 1 G are somewhat smaller than previously reported, but in line with those. At this early point in the analysis there are two main tentative points of interest in the average data: (a) It appears that the presence of the 2-line stimulus suppresses the elevator illusion. (b) We do not find a change in slope of the VPEL-vs-pitch function with the increase in G. I will reserve further comment until all the data are in and we have had an opportunity to work it over.

C. Theoretical Work

We have reported some of our efforts on the Great Circle Model: Although our original submission of Article 1 did not contain any more than a single line on the model, in a final version we have included a brief presentation of a first formulation of it; some further indication of the model is in Article 2.

The geometrical (projective) aspect of the treatment (based on the spherical approximation to the eye) so far has allowed us to do a number of things that we could not otherwise do: It pointed us toward understanding the fundamental identities between line stimuli in the pitch and roll planes. It also allowed us to examine intelligently questions regarding the possible influences of accommodation, and several retinal gradients on the slope of the VPEL-vs-pitch function. The fact that we can dismiss these latter factors (as noted above) implies that influences of aspects of retinal stimuli on spatial localization and orientation are quite different than for pattern (or form) perception. This work also led us to recognize the basic bilateral symmetry in influences on spatial localization and orientation, a failure of bilateral parity that would be totally unacceptable for pattern perception (cf., Article 5). This has also led us to a hypothesis regarding the evolutionary basis for partial decussation in the visual system (cf., Article 5). (Although this [as any evolutionary hypothesis] is, of course, somewhat speculative, it does appear to us to be considerably superior to any that has been previously proposed on the matter.

The Great Circle Model is not simply geometry, however. We have several semi-independent theoretical statements regarding control of the influence on VPEL of the pitched-from-vertical lines and their counterparts at identical

retinal locations from other stimulus planes. The inference we draw from the combination of geometry and our experimental work is that for the stationary eye in primary position the location of the intersection of the great circle containing the image of the line segment with the central vertical retinal meridian (CVRM) is the key to determining the magnitude of the influence of the line on VPEL; the intersection of the same great circle with the midfrontal plane (MFP) is the key to determining the magnitude of the influence of the line on VPV. As the statements above indicate, we have evidence for an opponent-type process for the way in which the influences on VPEL from nonparallel lines combine and for an exponential function for the way in which parallel line segments combine. These statements have fingers extending into the realm of neurophysiology. Some of this is summarized in Articles 1 and 2. As indicated there, a number of similarities between the properties of the psychophysical results and the properties of single units in area 7a of posterior parietal cortex suggest that it would be profitable to explore the connection further. We have made some arrangements to begin some such explorations.

We are also continuing to develop further extensions of the Great Circle Model incorporating the near-spatiotopic results into a generalized version.

In effect, our experiments have tied more things together and answered more questions than we initially asked of them. Our theoretical work is now doing the same. As indicated in the description above the program initiated is on course. We are carrying out experiments essentially as originally proposed. We are able to carry our theoretical work further than originally specified in the proposal. The work at both Columbia and Brandeis is continuing at a good pace. Some of the experiments that will be carried out this year are indicated in the descriptions above. Most of the others are in the original proposal. There are no major deviations in our plans for this year from those originally proposed.

D. Publications

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Articles

1. Matin, L. and Li, W. (1992). Visually perceived eye level: Changes induced by a pitched-from-vertical 2-line visual field. *Journal of Experimental Psychology: Human Perception and Performance*. 18, 257-289.
2. Matin, L. and Li, W. (in press-a). Mislocalizations of visual elevation and visual vertical induced by visual pitch: The great circle model. In B. Cohen, D. Tomko and F. Guedry (eds.), *Symposium on Sensing and Controlling Motion: Vestibular and Sensorimotor Function* (Chapt. 20). *Annals of the New York Academy of Sciences*.
3. Li, W. and Matin, L. (in press-b). Visual direction is corrected by a hybrid extraretinal signal. In B. Cohen, D. Tomko and F. Guedry (eds.), *Symposium on Sensing and Controlling Motion: Vestibular and Sensorimotor Function, Annals of the New York Academy of Sciences*.
4. Matin, L. and Li, W. (in press-c). Light and dark adaptation of visually perceived eye level controlled by visual pitch. *Perception and Psychophysics*.
5. Matin, L. and Li, W. (submitted for publication). Bilateral parity violation in visual processing of egocentric spatial localization: With implications for the evolution of partial decussation.

Abstracts of Presentations at Meetings and Symposia

1. Matin, L. (1991). Human visual orientation from a new perspective. *Clarence H. Graham Memorial Symposium*, Eastern Psychological Association, New York, Apr. 11-14, 1991, 62, 30.
2. Matin, L. and Li, W. (1991). Separate mechanisms for perceived eye level and perceived vertical: Dissection by pitch and roll of a 2-line stimulus. *Investigative Ophthalmology & Visual Science (Suppl.)*, 32, 900.
3. Li, W. and Matin, L. (1991). Spatial summation of influences on visually perceived eye level from a single variably-pitched 1-line stimulus. *Investigative Ophthalmology & Visual Science (Suppl.)*, 32, 1272.
4. Matin, L. and Li, W. (1991). Mislocalizations of visual elevation and visual vertical induced by visual pitch: The great circle model. *Symposium on Sensing and Controlling Motion: Vestibular and Sensorimotor Function*, July 7 - 11, Palo Alto, CA.
5. Li, W. and Matin, L. (1991). Visual direction is corrected by a hybrid extraretinal signal. *Symposium on Sensing and Controlling Motion: Vestibular and Sensorimotor Function*, July 7 - 11, Palo Alto, CA.
6. Matin, L. and Li, W. (1991). The Great Circle Model of spatial localization and visual perception of elevation. *Society for Neuroscience Abstracts*, 17, pt. 1, 848.
7. Matin, L. and Li, W. (1991). Visually perceived eye level, visually perceived vertical, and the Great Circle Model. *Bulletin of the Psychonomic Society*, 29(6), 526.
8. Li, W. and Matin, L. (1991). The influence of line orientation on visually perceived eye level is spatiotopic. *Bulletin of the Psychonomic Society*, 29(6), 488.
9. Matin, L. and Li, W. (submitted for presentation, 1992). Light and dark adaptation of egocentric spatial localization.
10. Li, W. and Matin, L. (submitted for presentation, 1992). Linear averaging of the influences from 2 lines of different pitch or obliquity on visually perceived eye level.

Colloquia

"How High Is Up? Visual Localization and the Great Circle Model."

Different versions of different lengths were presented for different audiences. At Indiana, a two hour evening presentation was to faculty of diverse backgrounds and from a number of different academic departments; at MIT presentation was to the faculty and students of the Department of Brain and Cognitive Sciences; at Smith-Kettlewell presentation was to a community of researchers in vision.

1. Indiana University, Inst. for the Study of Human Capability: Feb. 27, 1991
2. MIT, Dept. of Brain and Cognitive Sciences: Oct. 3, 1991
3. Smith-Kettlewell Institute for Visual Science: Nov. 25, 1991